Impact of deep transports over sloping bathymetry on the vertical structure of the Atlantic meridional overturning circulation

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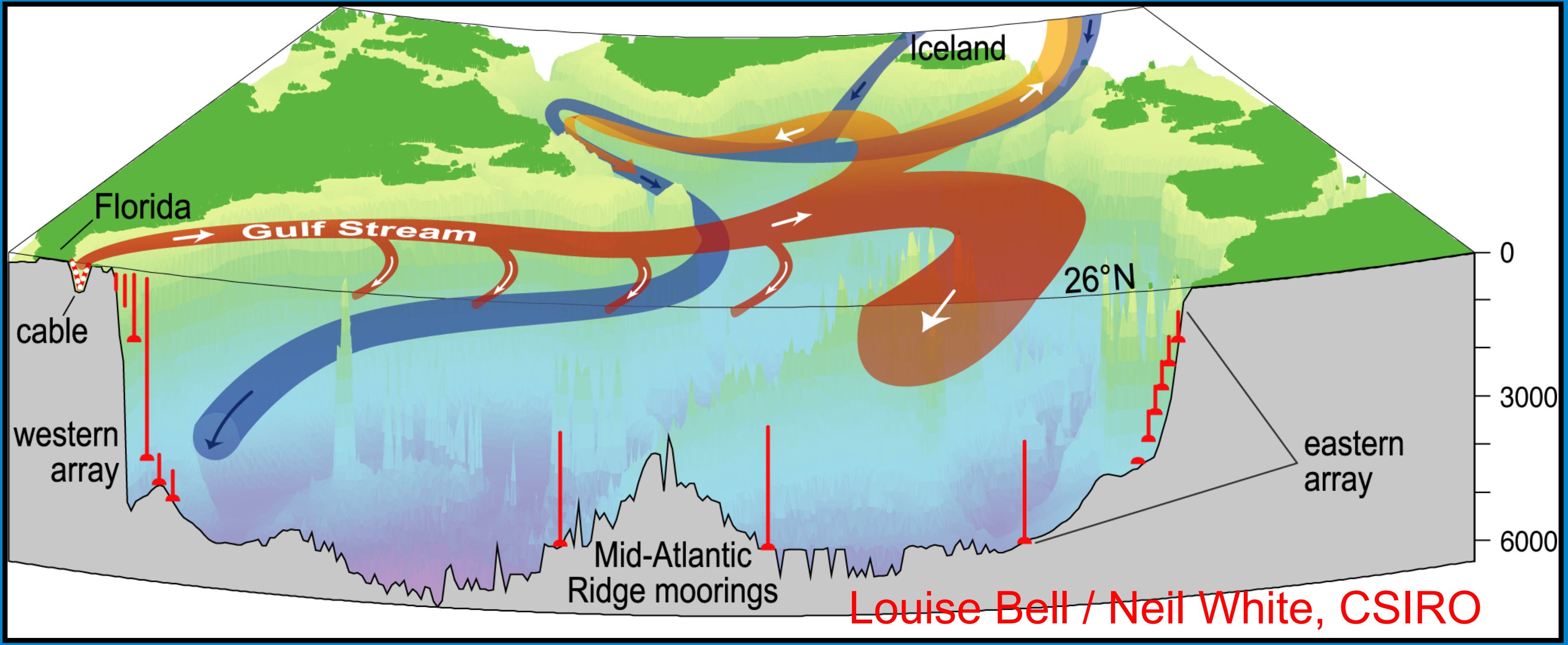
and the RAPID Team

The RAPID / MOCHA* array



Measurement components

- Gulf Stream : telephone cable
- Ekman : scatterometer
- Mid-ocean : density, current meters

* NERC / UK RAPID Climate Change Programme
NSF / US Meridional Overturning and Heat Transport in the Atlantic

Dynamic decomposition of MOC velocity field

after Lee and Marotzke (1998)

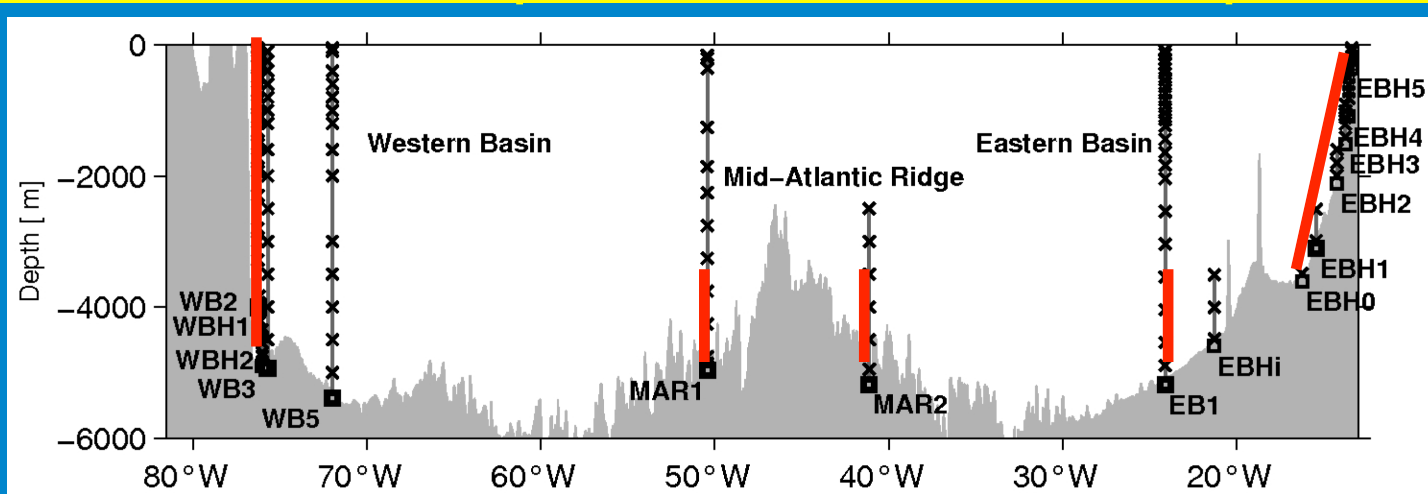
$$v(x,z) = \frac{1}{H}\int_{Z=-H}^{Z=0} v(x,z)\,dz + \left[v_{EK}(x,z) - \frac{1}{H}\int_{Z=-H}^{Z=0} v_{EK}(x,z)\,dz \right] + v_{SH}(x,z)$$

„External mode“
(barotropic flow
Over bathymetry)

Ekman
minus
compensation

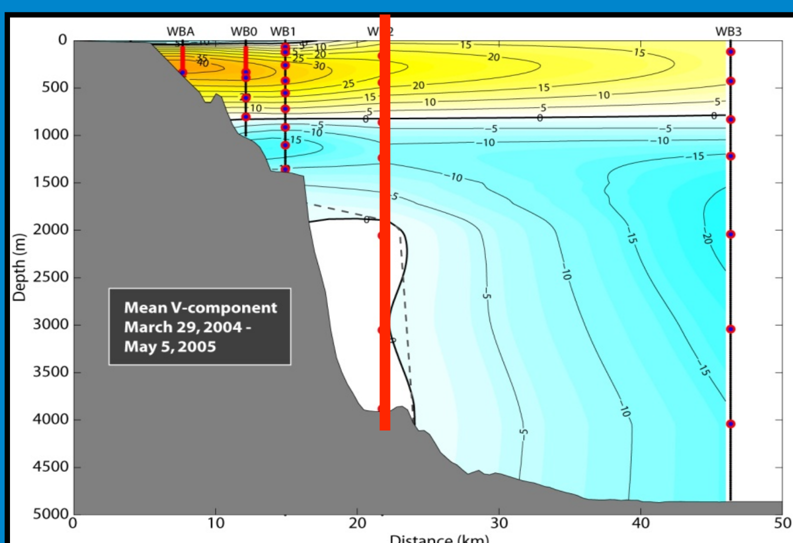
Vertical shear
(Thermal wind)

Mid-Ocean transports: Observed Components



$$T_{INT}(z) = -g/(\rho f) \int_{Z_{REF}}^{0} [\rho_{EAST}(z) - \rho_{WEST}(z)]dz$$

Basin wide integrated internal transports (T_{INT}) from zonal density gradient



Transport through western boundary wedge (T_{WBW}) from current meter measurements

Johns et al. (2008)

Mid-Ocean transports: Uniform compensation

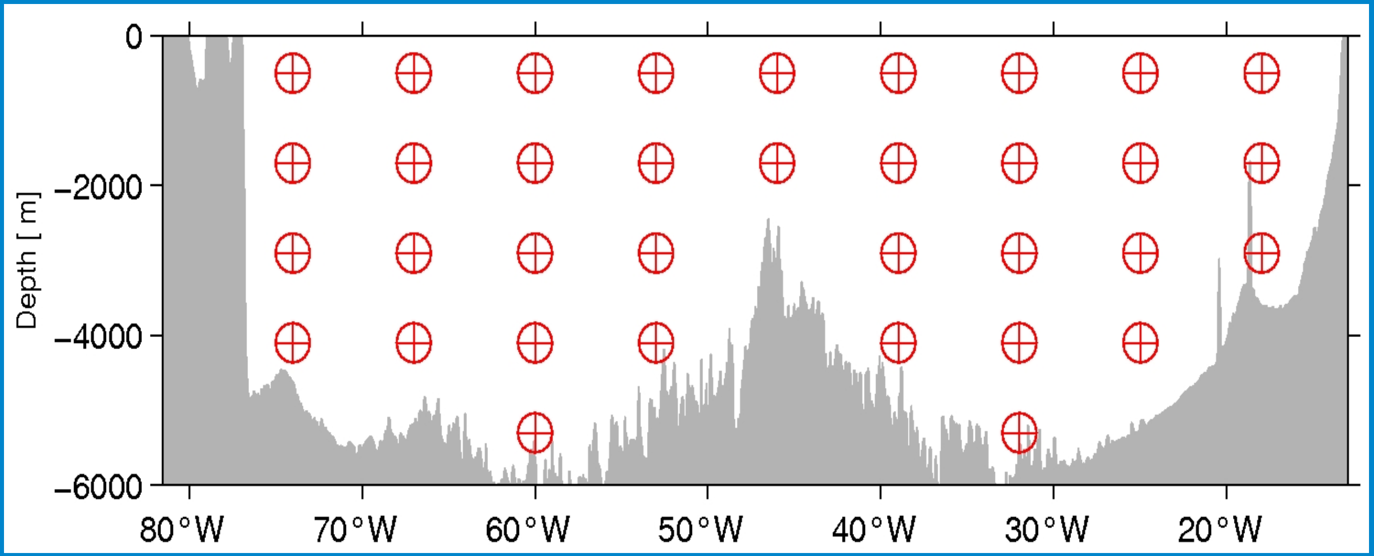
$$\int_{Z=-H}^{Z=0} T_{EK}(z) + T_{GS}(z) + T_{MO}(z)\,dz = 0$$

Constraint to derive absolute transport: Zero-net-flow across 26.5°N at each time step

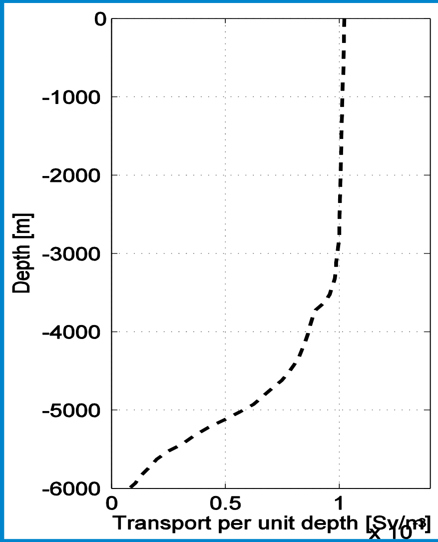
$$T_{MO}(z) = T_{WBW}(z) + T_{INT}(z) + T_{COMP}(z)$$

Compensation transport (T_{COMP})

Zonally uniform, barotropic compensation velocity



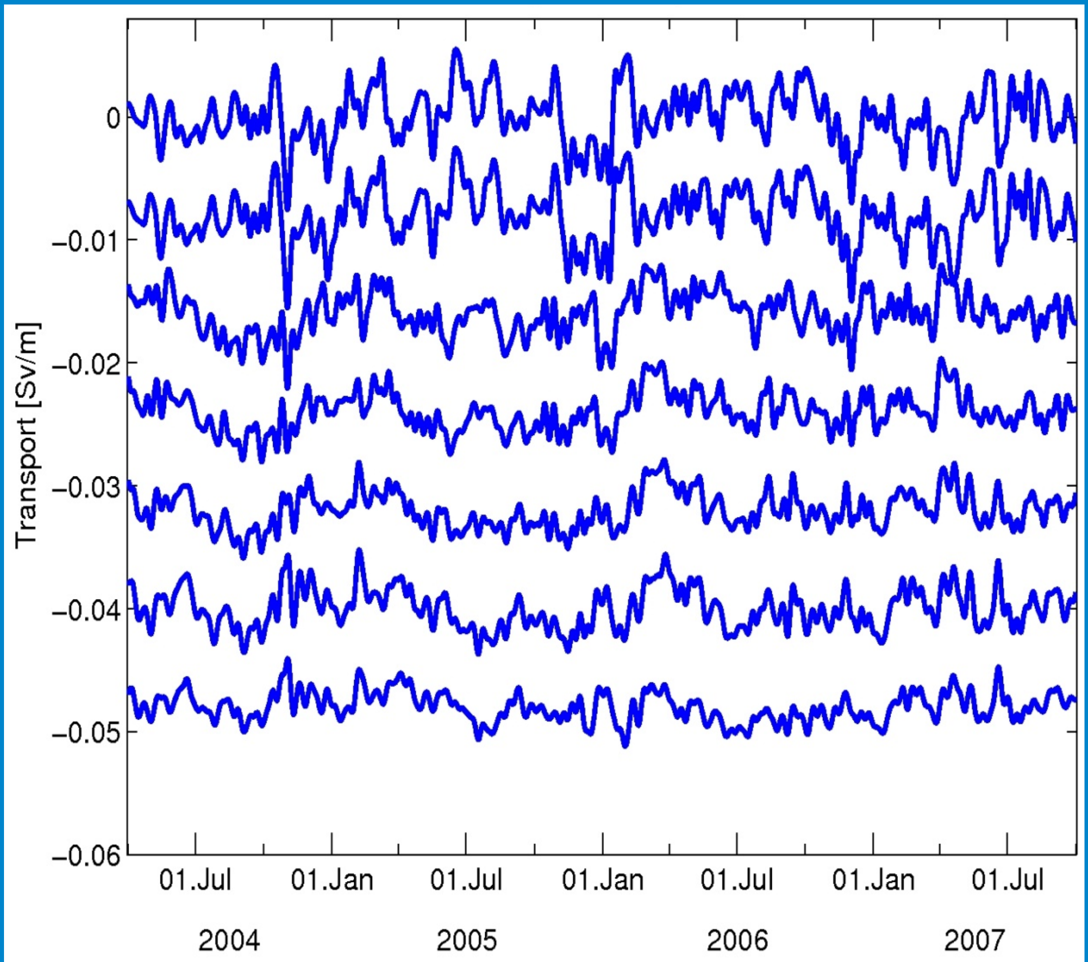
Compensation transport profile



➔ Barotropic velocity over sloping bathymetry gives baroclinic transport profile

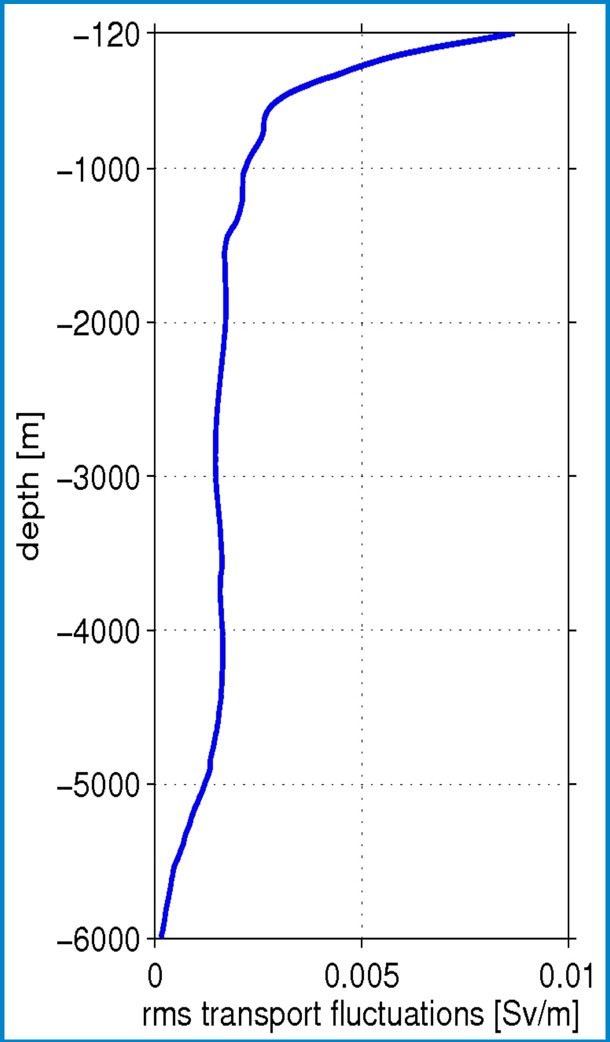
Mid-Ocean transport below 1000 m

Fluctuations of Mid-ocean transport (per-unit-depth) at selected depth levels



Depth
1000
1500
2000
2500
3000
3500
5000

rms transport fluctuations

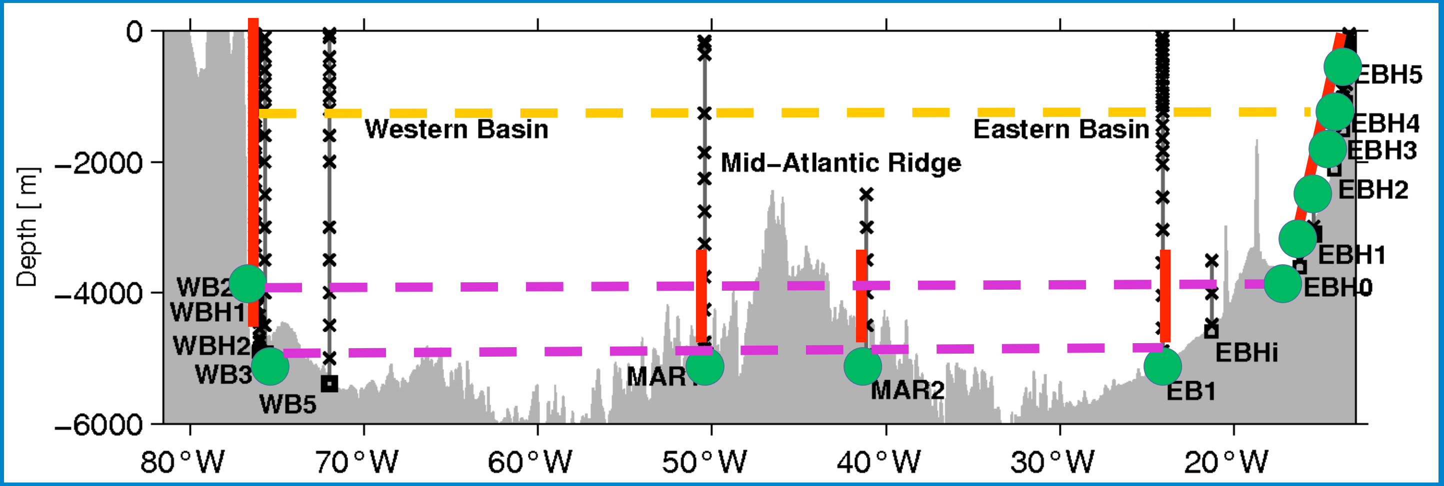


➔ Magnitude of transport fluctuations is uniform between 1000 and 5000 m

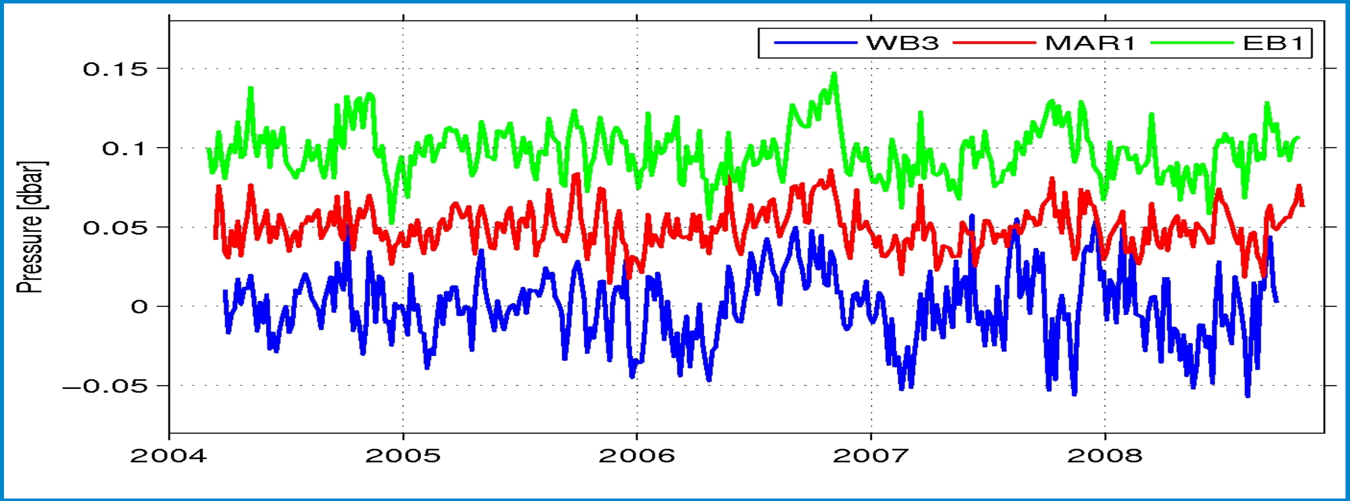
Outline

- ➔ Is zonally uniform compensation a good approximation?
- ➔ Comparison of compensation with bottom pressure derived transports
- ➔ Discrepancies between the two approaches consistent with zonally non-uniform compensation

Mid-ocean transports fluctuations from bottom pressure



Bottom pressure fluctuations at three different sites (offset 0.05 dbar)

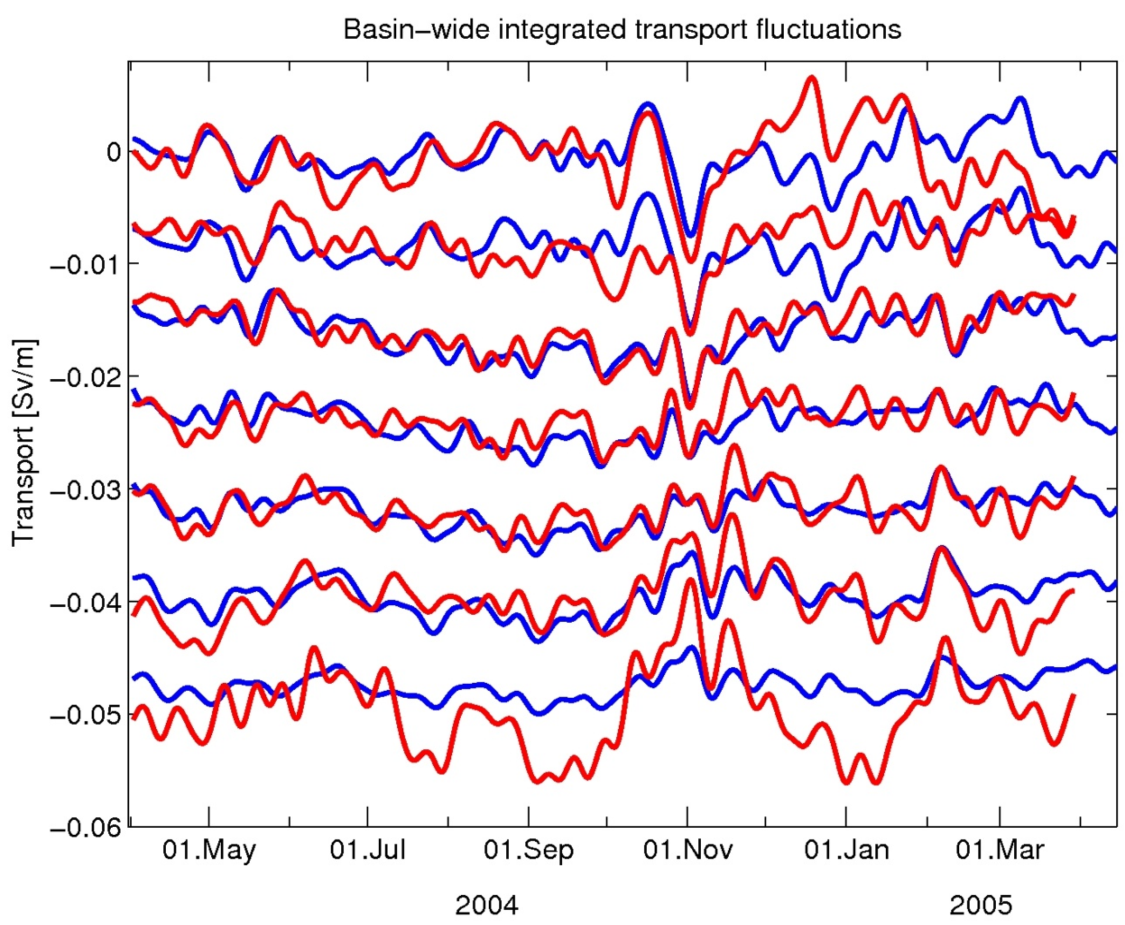


$$T_{MO}(z)' = \frac{1}{\rho f}\left[p_E(z)' - p_W(z)'\right]$$

Mid-ocean geostrophic transport fluctuations

Mid-Ocean transport: Compensation and bottom pressure approach

Fluctuations of mid-ocean transport (per-unit-depth)



Depth

1000

1500

2000

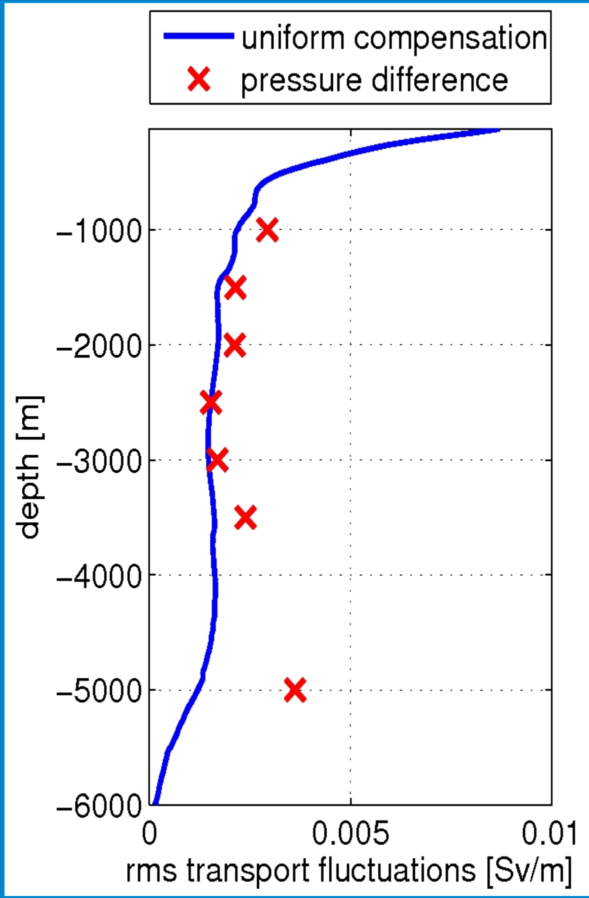
2500

3000

3500

5000

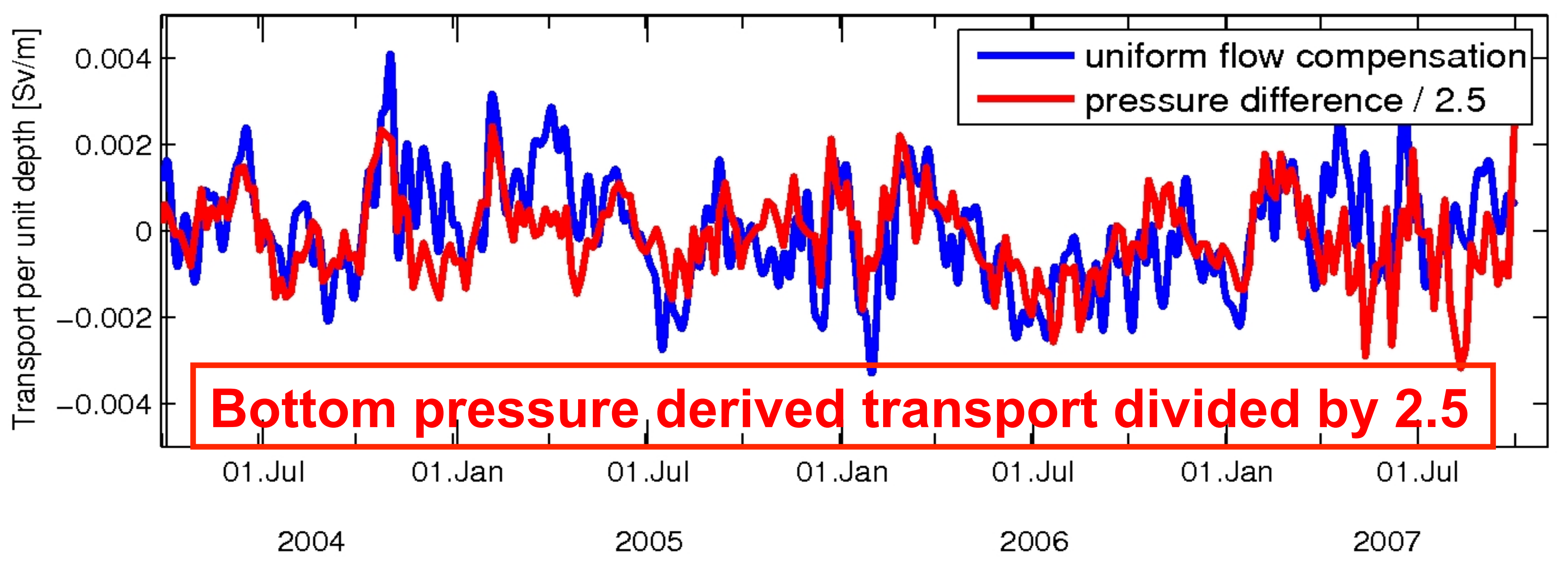
r.m.s. transport fluctuations



➔ Mismatch in amplitude of transport fluctuations at 5000 m by a factor of 2.5

Abyssal Mid-ocean transport:Compensation and bottom pressure approach

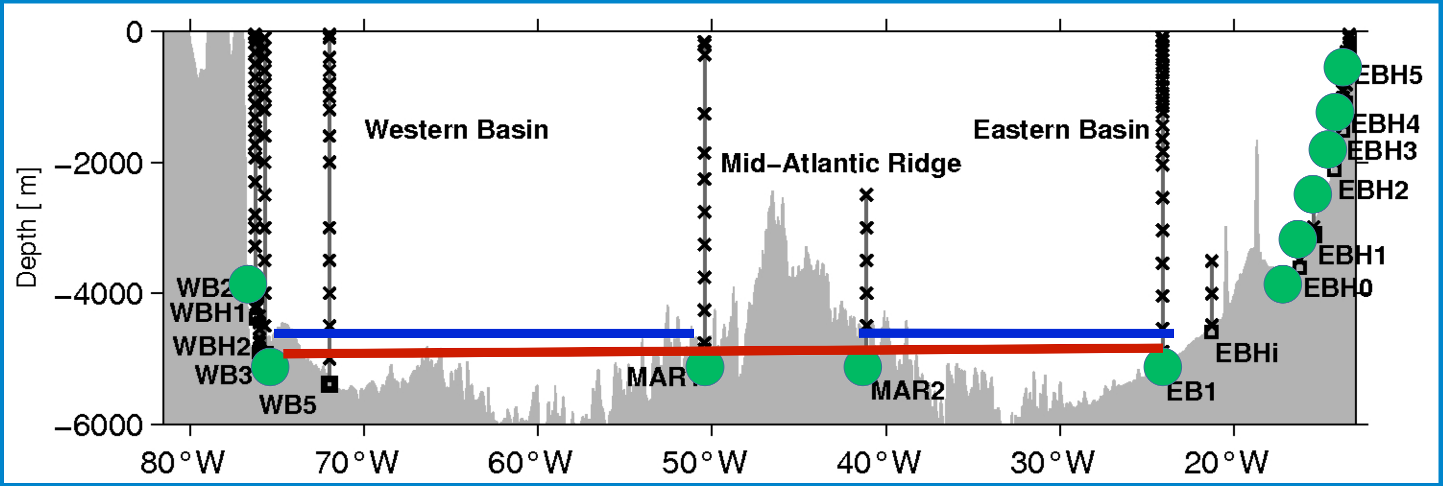
Mid-ocean transport fluctations at 5000 m



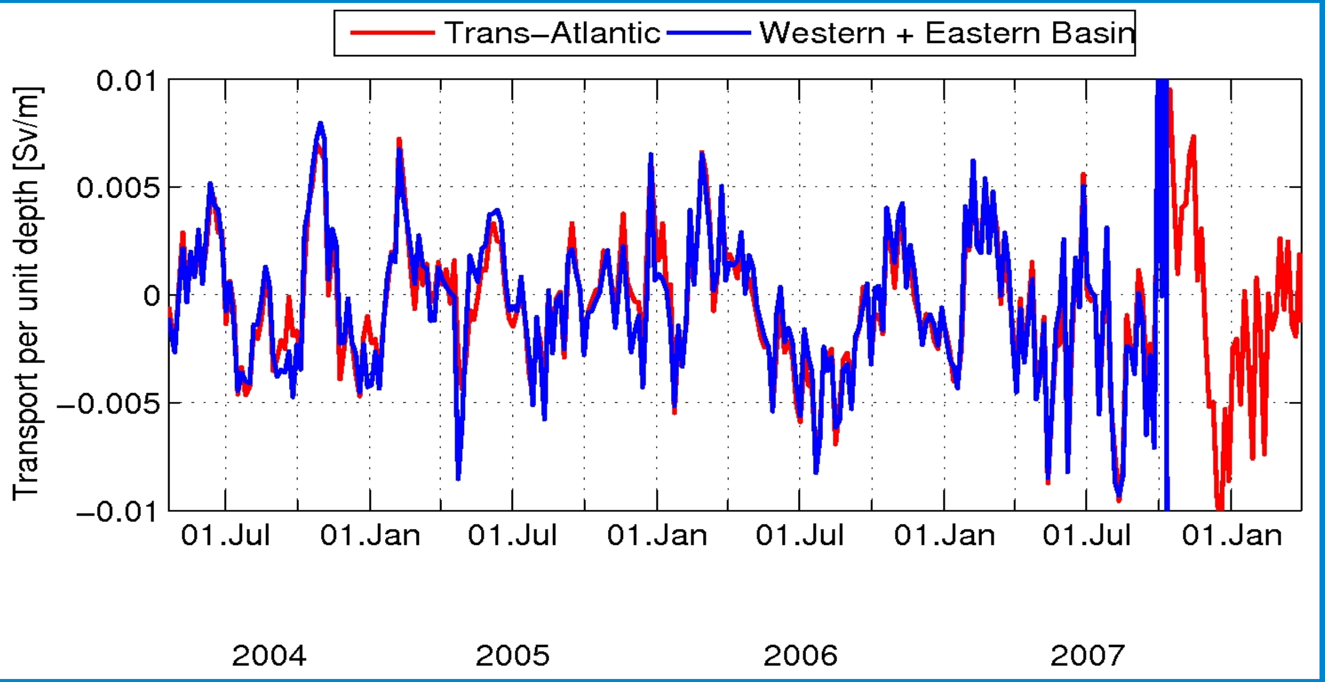
➔Clear positive correlation between the two independent time series

➔ yet rms amplitudes are different

Pressure gradients across the Mid-Atlantic Ridge?

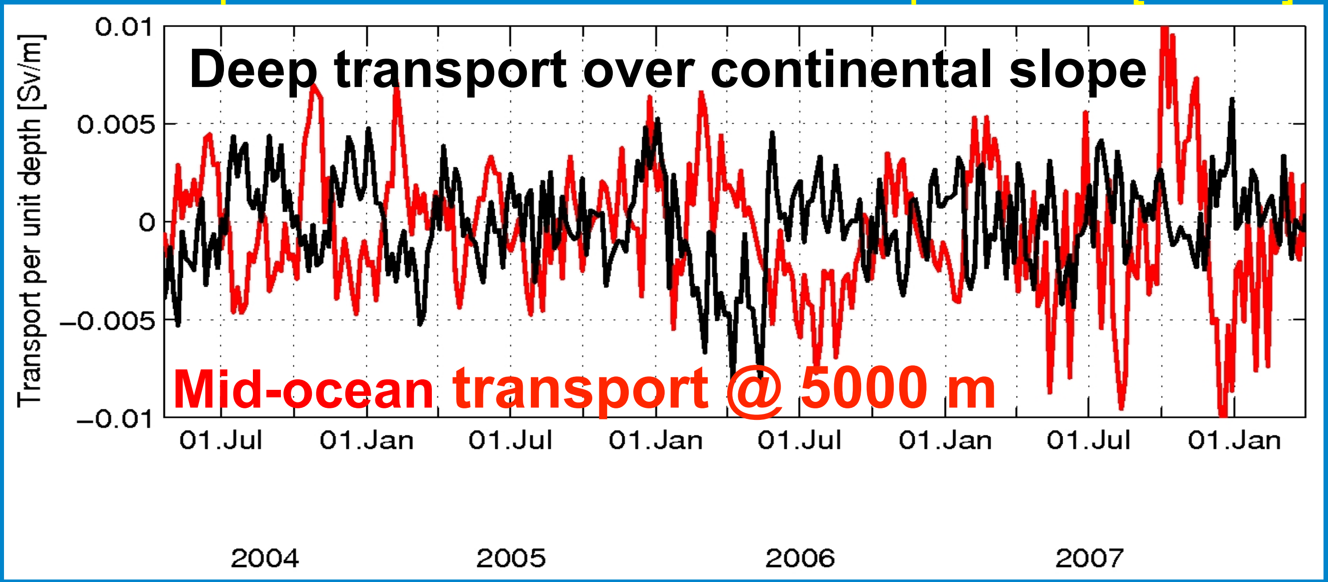


➔P gradient across MAR much smaller than Trans-atlantic one



Deep flow over eastern boundary continental slope?

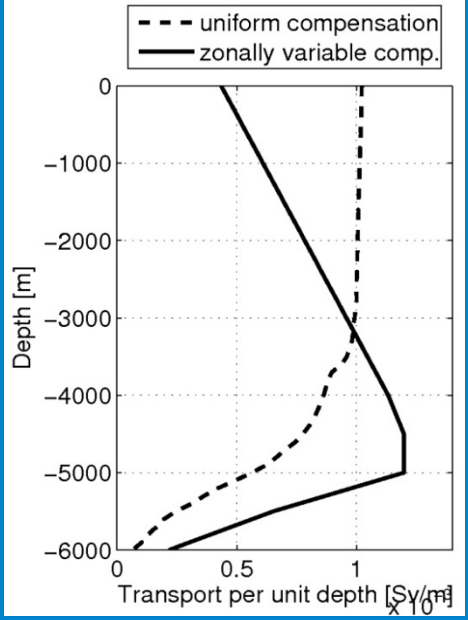
Transport fluctuations from bottom pressure [Sv /m]



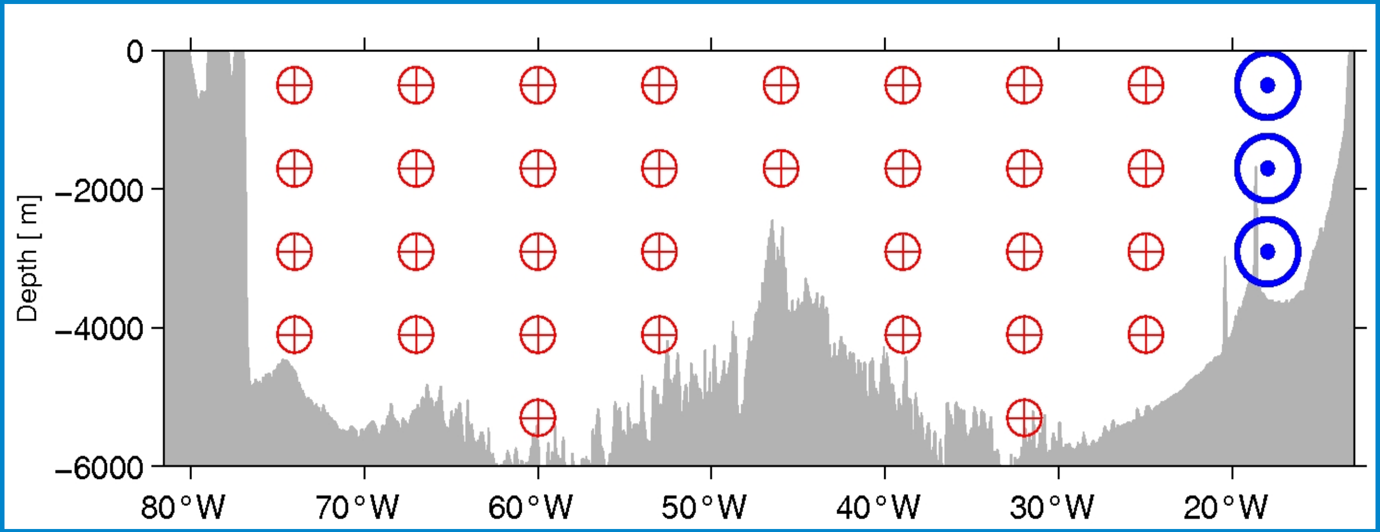
Abyssal mid-ocean transport is 180° out of phase with deep eastern continental slope transport

➔ Consistent with waves or eddies passing over EB1

Compensation profiles

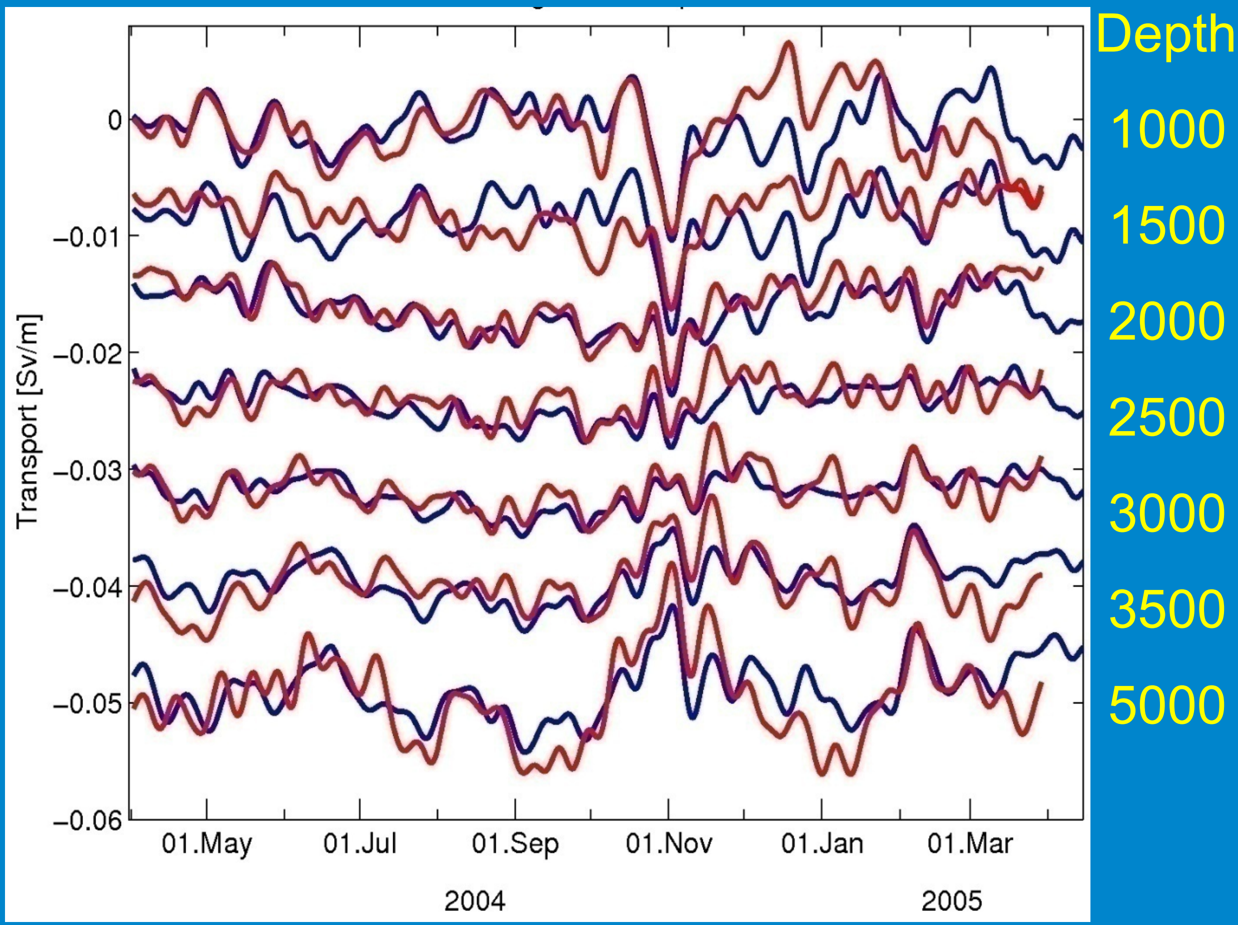


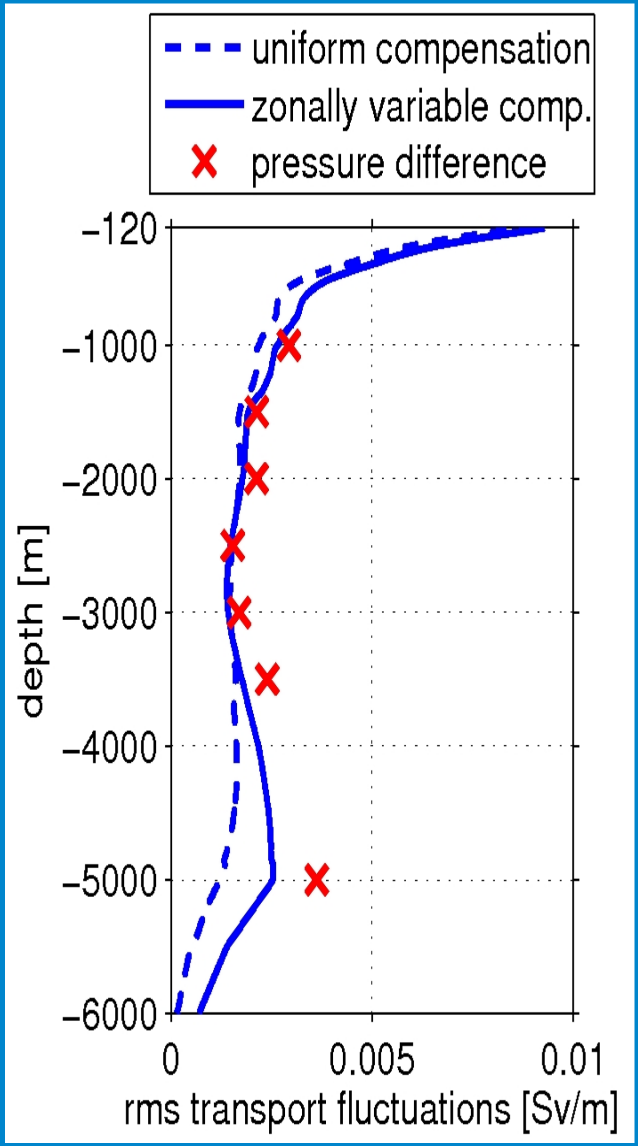
Compensation velocity: Counter-flow over continental slope



Application of zonally variable flow compensation

Fluctuations of mid-ocean transport
(per-unit-depth)



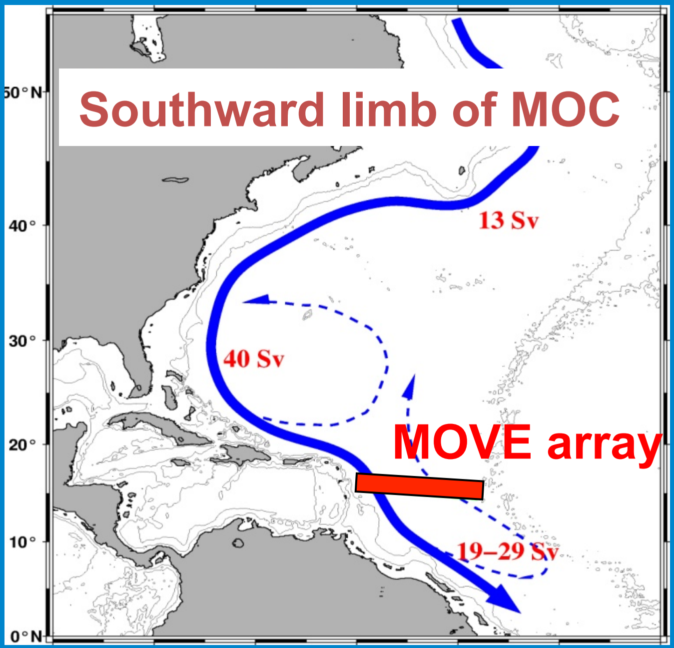


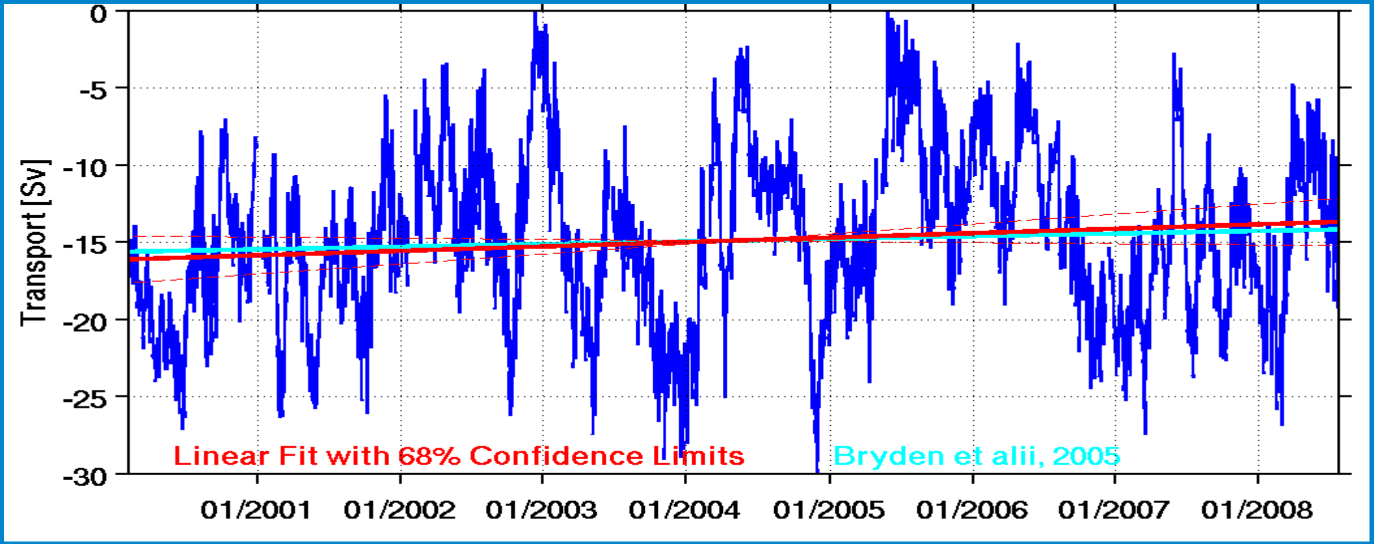
➔Amplitudes of transports fluctuations at 5000 m agree much better

➔ AMOC fluctuations increase, because compensation acts at larger depths

An 8-year long time series of NADW transport in the tropical North Atlantic:

… see poster by Lanckhorst et al.





Suggested MOC transport decrease of 3 Sv / 10years

Conclusions

➔ Bottom pressure derived transport fluctuations in good agreement with uniform compensation derived ones between 1000 and 3000 m

➔ Descrepancy of a factor of 2.5 at 5000 m (however, positive correlation)

➔ Abyssal Atlantic transport 180° out-of-phase with eastern continental slope

➔ Accordingly modified compensation reduces deep transport mismatch

➔ Out-of-phase flow over sloping bathymetry implies larger AMOC variability

➔ Representation of external mode important for vertical structure of AMOC